09/480,164 = US 6,334,405
corr. to JP 2000-328236

SPECIFICATION

VACUUM ARC EVAPORATION SOURCE AND VACUUM ARC VAPOR DEPOSITION APPARATUS

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a vacuum arc evaporation source and a vacuum arc vapor deposition apparatus provided with the vacuum arc evaporation source.

BACKGROUND OF THE INVENTION

A vacuum arc vapor deposition apparatus has been heretofore known in which an arc discharge with an evaporation material being a cathode is generated in a vacuum chamber, and a cathode material is evaporated and ionized by energy of an arc current to accumulate films on a substrate.

Such a vacuum arc evaporation apparatus has a disadvantage that molten particles having a diameter in excess of a few μm which is far larger than that of evaporated particles and ionized particles are unavoidably generated, which are mixed into films, resulting in deterioration of coarseness of film surface and unevenness of film composition.

There has been proposed to solve such a problem caused by the molten particles as described above by generation of a magnetic field. For example, in Japanese Patent Application Laid-Open No. 2-194167 Publication is disclosed that an air-core coil coaxial with an evaporation surface is provided between the evaporation surface and a substrate. According to the constitution disclosed therein, electrons in a plasma are wound around the

taken the following technical means. That is, the feature of a vacuum arc evaporation source according to the present invention, lies in the provision of an evaporation material as a cathode of arc discharge, and a magnetic field generating source arranged so that a magnetic field generating source surrounds the evaporation material, and all the lines of magnetic force crossing the evaporation surface of the evaporation material crosses substantially vertically to the evaporation surface.

According to the constitution as mentioned above, molten particles can be reduced similar to the prior art by the lines of magnetic force crossing the evaporation surface. Since the lines of magnetic force substantially vertically cross the evaporation surface, unlike the prior art, the arc spot is hard to be deviated on the evaporation surface, and the evaporation material is uniformly consumed.

The lines of magnetic force need not cross the evaporation surface completely vertically, but may cross the evaporation surface substantially vertically. The substantially vertical termed in the present invention indicates within ± 30 degrees with respect to normal line of the evaporation surface. If in the range as described, this is within an allowable range capable of achieving uniform consumption of the evaporation material to some extent. Accordingly, the magnetic field generating source may be arranged at a position so that the lines of magnetic force assume a direction as described.

Preferably, the magnetic field generating source is arranged so that the

diametral magnetic field generating source are directed in the same direction. In this case, the number of lines of magnetic force extending through the evaporation material increases, that is, the intensity of magnetic field becomes high to obtain the aforementioned effect more strongly.

Further, according to the present invention, the magnetic force generating source may comprise a first magnetic field generating source having magnetic poles on the inner peripheral side and on the outer peripheral side, and a second magnetic field generating source in which magnetic poles on the inner peripheral side and on the outer peripheral side are different from those of the first magnetic field generating source and arranged in an axial direction of the first magnetic field generating source.

According to the constitution as described above, extension of the magnetic field generating source in an axial direction is small, which is preferable. In this case, if the outer peripheral sides of the first magnetic field generating source and the second magnetic field generating source are connected by a magnetic material, extension of the magnetic field sideward is rarely present, and so, where a plurality of evaporation sources according to the present invention are provided in a vacuum container, an influence of next evaporation source can be eliminated.

Further, for obtaining the similar effect, the magnetic field generating source may be constituted as a permanent magnet having a U-shape in section having both N and S magnetic poles on the in-diametral side.

In the more preferable constitution according to the present invention,

evaporation material is evaporated and adhered to the member, resulting in a possible occurrence of inferior insulation. However, if the insulator is constituted as a clearance, such a possible adhesion disappears and the inferior insulation is prevented.

More preferably, a direction changing means for changing lines of magnetic force to a direction inclined on the peripheral edge with respect to normal line formed on the evaporation surface is provided in the vicinity of a central portion of the evaporation material. Thereby, concentration of arc on the central portion of the evaporation surface is prevented, resulting in uniform consumption.

Means for imparting a change to a direction of lines of magnetic force from the magnetic field generating source that can be employed includes a magnet, a coil or a magnetic material. When the magnet, the coil or the magnetic material is arranged on the back side of the central portion of the evaporation material, the lines of magnetic force in the vicinity of the center are drawn to the magnet, the coil or the magnetic material, whereby the lines of magnetic force in the vicinity of the center are inclined outward with respect to normal line. When the central lines of magnetic force are inclined outward, concentration of arcs on the central portion of the evaporation surface is prevented, due to the characteristic that the arc tends to move in the inclining direction of lines of magnetic force, and uniform consumption results.

A horizontal magnetic force component is generated on the evaporation

evaporation surface in the present invention;

FIGS. 6A and 6B are respectively sectional side views showing an evaporation source as a comparative example relative to the present invention, 6A being showing that the line of magnetic force is inward, 6B being showing that the line of magnetic force is outward;

FIGS. 7a and 7b show respectively evaporation sources according to a second embodiment of the present invention, 7a being a side view, 8b being a front view;

FIG. 8 is a sectional side view showing an evaporation source according to a third embodiment of the present invention;

FIGS. 9a and 9b show respectively evaporation sources according to a fourth embodiment of the present invention, 9a being a sectional side view, 9b being a front view;

FIGS. 10a and 10b show respectively evaporation sources according to a fifth embodiment of the present invention, 10a being a sectional side view, 10b being a front view;

FIG. 11 is a schematic constituent view of a vacuum arc vapor deposition apparatus according to a sixth embodiment of the present invention;

FIG. 12 is a front view of an evaporation source according to a sixth embodiment of the present invention;

FIG. 13 is a sectional view showing a change of lines of magnetic force caused by an annular magnetic material surrounding the outer periphery of the evaporation material;

9 together with a magnetic field generating source 7 for generating a magnetic field crossing substantially vertical to the evaporation surface of the evaporation material 3. While in FIG. 1, there is illustrated a single magnetic field generating source unit 9 provided in the vacuum container 2, it is preferable that a plurality of the sources 9 are provided on the side walls of the vacuum container 2 so as to surround the coating substance to be processed 5.

As shown in FIG. 3, the evaporation material 3 is formed like a disk, and the surface thereof on the coating substance to be processed 5 side is the arc evaporation surface 11. The magnetic field generating source 7 constituting an evaporation source 9 together with the evaporation material 3 comprises an annular permanent magnet having annular magnetic poles on both ends in an axial direction (in a thickness direction). The magnetic field generating source 7 is arranged so as to surround the evaporation material 3 coaxial with the evaporation material 3. The magnetic field generating source 7 is arranged so that an axial central position thereof is substantially registered with a position of the evaporation surface, an end on the coating substance to be processed 5 side (the forward surface) being N-pole, the other end being S-pole. Note that the magnetic poles may be reversed. The thus arranged magnetic field generating source 7 generates a magnetic field as shown in FIG. 2.

Further, where a permanent magnet is employed as the magnetic field generating source 7, it is large in magnetic field strength as a magnetic field

efficiency of the evaporation material is very high. It is noted that the direction of the rotating movement is reversed according to the direction of the line of magnetic force.

Further, since the rotating radius of the arc spot varies at random, a local rise in temperature of the evaporation material is suppressed, and generation of molten particles is suppressed.

FIG. 6 shows, as a comparative example, images of arc spots where a line of magnetic force is greatly inclined from a normal direction of the evaporation surface 11. When as shown in FIG. 6A, the magnetic field generating source 7 is greatly deviated forward (the coating substance to be processed 5 side) relative to the evaporation surface 11 of the evaporation substance 3, the line of magnetic force is greatly inclined inward in the evaporation surface 11. Accordingly, the arc spot is discharged concentratively in the central part of the evaporation surface 11.

On the other hand, when it is greatly deviated backward as shown in FIG. 6B, the line of magnetic force in the evaporation surface is greatly inclined outward. Accordingly, the arc spot is discharged only at the side edge portion of the evaporation surface 11, and the arc spot is flied out of the evaporation substance 3 and the arc discharge tends to stop. In both case of FIGS. 6A and 6B, the evaporation materials 3 is not uniformly consumed, and the utility efficiency is poor.

It is preferable for preventing such an inconvenience as noted above to make the direction of the line of magnetic force on the evaporation surface 11

directions of magnetic poles put in order to constitute annular magnets having annular magnetic poles on both ends in an axial direction. The magnetic field generating source 17 is arranged similarly to the magnetic field generating source 7 according to the first embodiment, and operates with respect to the evaporation substance 3 similarly to the first embodiment.

FIG. 8 shows an evaporation source 29 according to a third embodiment of the present invention. A magnetic field generating means 27 of the evaporation source 29 comprises an in-diametral annular magnet 30 constituted and arranged similarly to the annular magnet 7 according to the first embodiment and an out-diametral annular magnet 31 arranged on the out-diametral side. The out-diametral annular magnet 31 is an annular magnet having magnetic poles on both ends in an axial direction, similar to the in-diametral annular magnet 30, axial thickness of which is substantially similarly constituted. The out-diametral annular magnet 31 is arranged coaxial with the in-diametral annular magnet 30 to surround the in-diametral annular magnet 30 so that the same magnetic poles are directed in the same direction.

As shown in FIG. 8, according to the magnetic field generating means 27 constructed as described above, the number of lines of magnetic force extending through the evaporation material 3 increases more than that of only the in-diametral magnet 30 owing to interaction of both the annular magnets 30 and 31. That is, the magnetic field strength in the evaporation

annular magnets 40 and 41 is substantially similar to the magnetic field generating source 7 according to the first embodiment, and when the evaporation surface 11 of the evaporation material 3 is positioned at an intermediate position between the inner peripheral magnetic poles of both the annular magnets 40 and 41, the magnetic field extends through the evaporation surface 1 substantially vertically.

Further, according to the present embodiment, since the magnetic material 42 connect the outer peripheral sides of both the magnets 40 and 41, the magnetic field is not generated on the outer peripheral side. Accordingly, where a number of evaporation sources 39 are arranged, as a unit, adjacent to one another in the vacuum container 2, the influence of the magnetic field on the evaporation sources 39 adjacent to one another can be effectively eliminated.

FIG. 10 shows an evaporation source 49 according to a fifth embodiment of the present invention. Annular magnets having a U-shape in section having both N and S magnetic poles on the in-diametral side constitute a magnetic field generating source 47 of the evaporation source 49. Also in the present embodiment, the evaporation material 3 is arranged so that the evaporation surface 11 is positioned at an intermediate position between both the magnetic poles, and the operation and effect similar to the fourth embodiment can be obtained.

It is noted that the present invention is not limited to the above-described embodiments. For example, the annular magnet that is a magnetic

shape instead of a circular ring.

The magnetic field generating source 7 is formed from a ring-like permanent magnet having magnetic poles on both ends in an axial direction X, and is arranged so as to surround the evaporation material. The magnetic field generating source 7 has N-pole on the end (forward surface) on the coating substance to be processed 5 side, and S-pole on the other end. The arrangement of magnetic poles may be reversed.

The ring-like magnetic material 13 is formed of, for example, carbon steel material, and is arranged so that an end 13a on the substance to be processed 5 side substantially faces to the evaporation surface 11.

The magnet (a fourth magnet) 14 as the line of magnetic force direction changing means is a permanent magnet, whose substance to be processed 5 side in an axial direction is S-pole, and the opposite side in an axial direction is N-pole. The magnetic poles of the magnetic field generating source 7 and the magnet 14 are provided oppositely as described above. Accordingly, if the magnetic poles of the magnetic field generating source 7 are reversed to those previously mentioned, the magnetic poles of the magnet 14 are also arranged reversely.

When the magnetic material 13 is provided, the line of magnetic force in FIG. 2 is as shown in FIG. 13. That is, out of the lines of magnetic force formed by the magnetic field generating source 7, those extending through the vicinity of the outer peripheral edge of the evaporation surface are drawn into the magnetic material 13 through which the lines of magnetic force tend

A is curved by the magnetic material 13 so that the magnetic material 13 side is high in magnetic flux density while the evaporation material 3 side is low in magnetic flux density. The arc A is pushed back on the evaporation material 3 side which is in the direction of low magnetic flux density due to the properties that the arc A moves in the direction of low magnetic flux density.

Further, as the arc A moves away from the magnetic material 1 and the self-forming magnetic field escapes from a region subject to be affected by the magnetic material 13, the pushing-back force is gradually reduced, and finally, there is not influenced (state of FIG. 14a).

By the operation as described above, confinement of the arc spot is carried out more positively.

Further, the magnetic material 13 and the evaporation material 1 are provided with the clearance 12 therebetween and are electrically insulated, thus positively preventing the arc from moving toward the magnetic material 13.

FIG. 15 shows an evaporation source 19 according to a seventh embodiment of the present invention. A magnetic field generating source 17 of the evaporation source 19 is constituted so that a number of permanent magnets are arranged annularly (ring-like) to form a magnetic field similar to the magnetic field generating source 7 according to the first embodiment. That is, a plurality of bar magnets 21 having magnetic poles on both ends in a longitudinal direction are arranged annularly with the directions of the

11. Suppose here that magnetic flux density of line of magnetic force is B, and an angle formed between the line of magnetic force and the evaporation surface 11 is θ, then the horizontal magnetic force component is $B\cos\theta$.

Due to the characteristic that the arc spot "moves in the direction opposite j x B" (wherein j is an arc current), the force of $F= -j \times B\cos\theta$ shown in FIG. 18 acts on the arc spot so that the arc spot rotates on the evaporation surface 11, but its region is enlarged so that the inclination of the line of magnetic force becomes large, thus making it possible to make moving rate of the arc spot higher in a wide range, as a consequence of which generation of droplets reduces.

It is noted that as the line of magnetic force direction changing means, an electromagnet for generating a similar magnetic field or a coil may be employed other than the permanent magnet. Also in this case, connection will suffice so that the direction of the magnetic pole is not repulsed to the line of magnetic force of the magnetic field generating source 7. Where an electromagnet or a coil is employed, preferably, a control device (not shown) for changing a value of an energizing current to the electromagnet or coil is provided.

By changing the intensity of magnetic force generated by the electromagnet by the control device, it is possible to change the number of lines of magnetic force (magnetic flux density) of the evaporation surface 11 and control a moving area and moving rate of the arc spot on the evaporation surface 11. As a result, arc discharge according to a degree of consumption

WHAT IS CLAIMED IS:

1. A vacuum arc evaporation source comprising:

an evaporation material which is a cathode of arc discharge; and

a magnetic field generating source which is arranged so as to surround said evaporation material and so that the lines of magnetic force crossing the evaporation surface of said evaporation material cross substantially vertical to said evaporation surface.

2. The vacuum arc evaporation source according to claim 1, wherein the magnetic field generating apparatus is arranged so that said lines of magnetic force are within ± 30 degrees with respect to normal line of said evaporation surface.

3 The vacuum arc evaporation source according to claim 1, wherein said evaporation surface is positioned substantially in an intermediate between both magnetic poles N and S of said magnetic field generating source.

4. The vacuum arc evaporation source according to claim 1, wherein said magnetic field generating source has magnetic poles on both ends in an axial direction.

5. The vacuum arc evaporation source according to claim 1, wherein

magnetic material to electrically insulate therebetween.

9. The vacuum arc evaporation source according to claim 1, further comprising:

a direction changing means for lines of magnetic force provided on the back side of a central portion of said evaporation material to change the direction of lines of magnetic line crossing in the vicinity of a central portion of said evaporation material to the direction inclined outward to the peripheral edge with respect to normal line formed on the evaporation surface.

10. The vacuum arc evaporation source according to claim 4, further comprising:

a magnetic material surrounding the outer periphery of said evaporation material and

a direction changing means for lines of magnetic force which is a magnet provided on the back side of a central portion of said evaporation material and having magnetic poles in an axial direction so that the polarities of said magnet and said magnetic field generating source are directed oppositely to each other.

11. The vacuum arc evaporation source according to claim 1, wherein said magnetic field generating source is permanent magnet

ABSTRACT

To provide an evaporation source and an arc evaporation apparatus in which an evaporation material as a cathode of arc discharge, and a magnetic field generating source arranged so that all lines of magnetic force crossing the evaporation surface of the evaporation material cross substantially vertically are arranged whereby the number of molten particles arriving at a substrate by the magnetic field can be reduced, and deviation of occurrence of arc spots can be suppressed.

FIG. 2

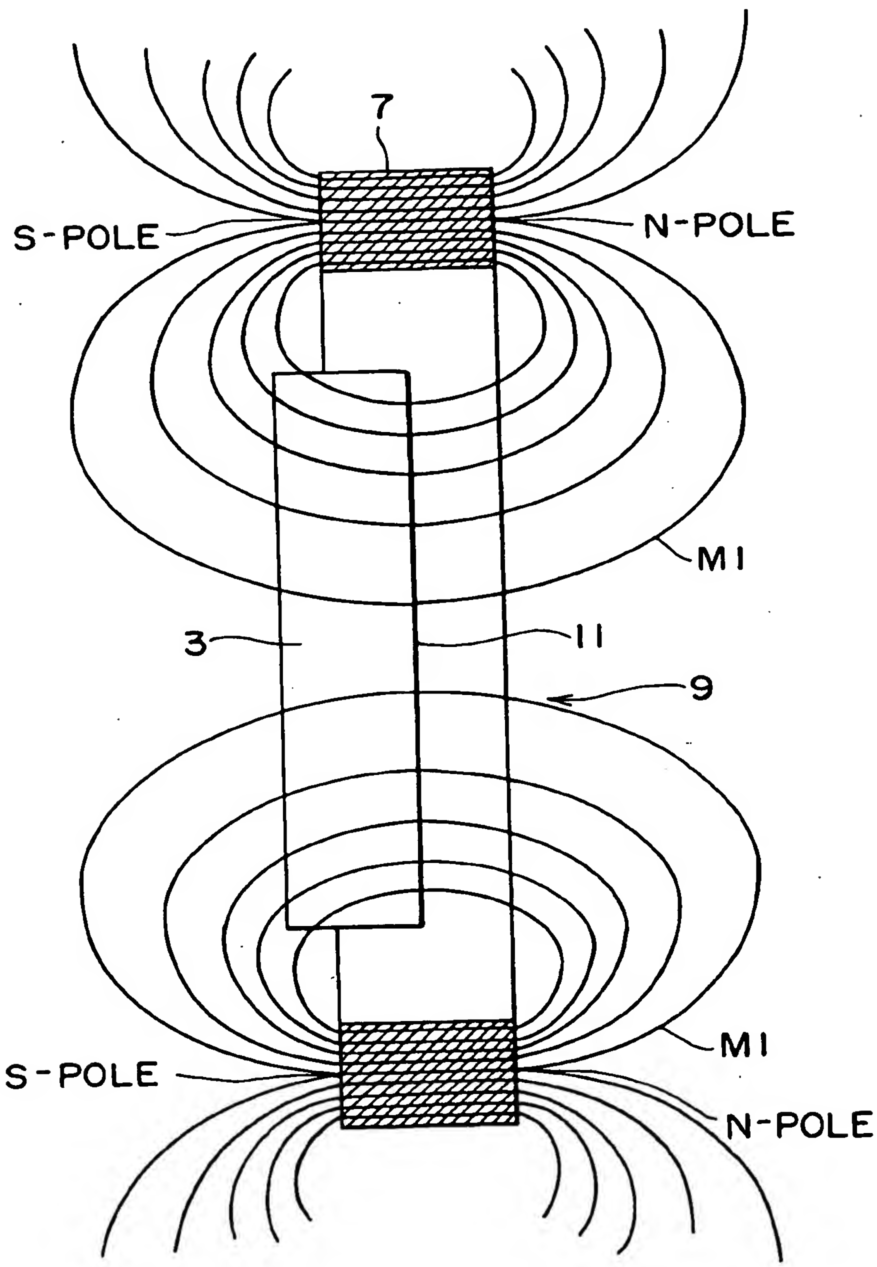


FIG.5A

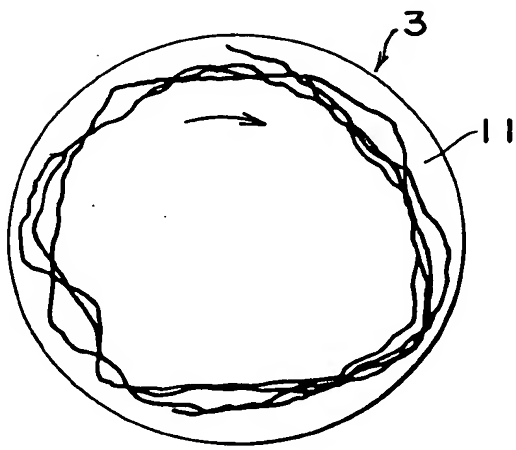


FIG.5B

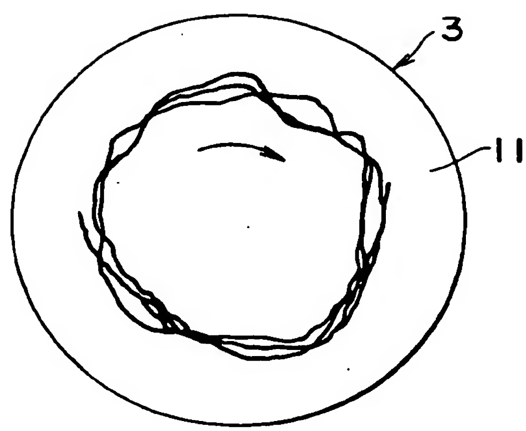


FIG.5C

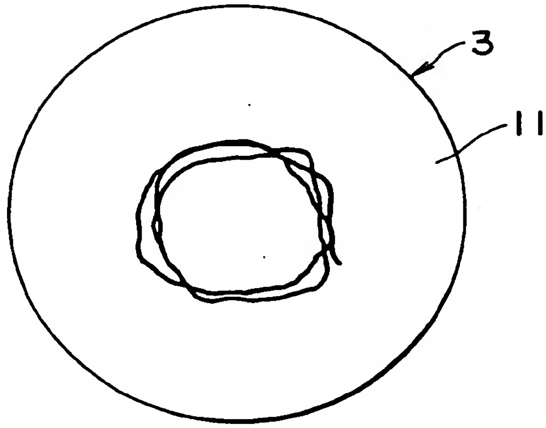


FIG.5D

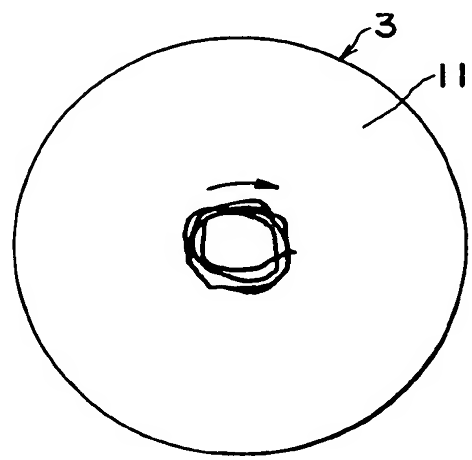


FIG. 7A

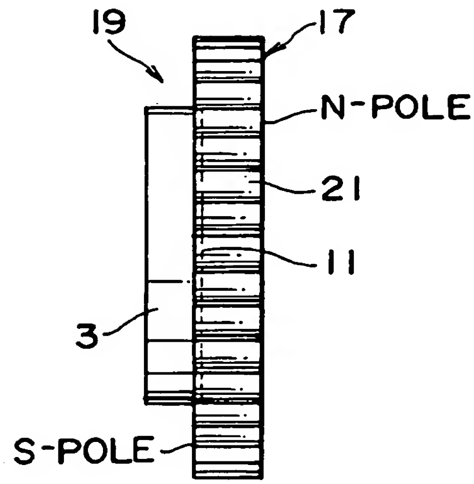


FIG. 7B

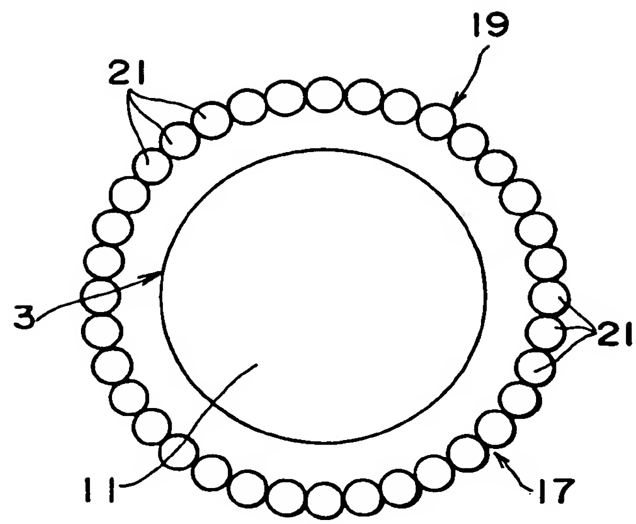
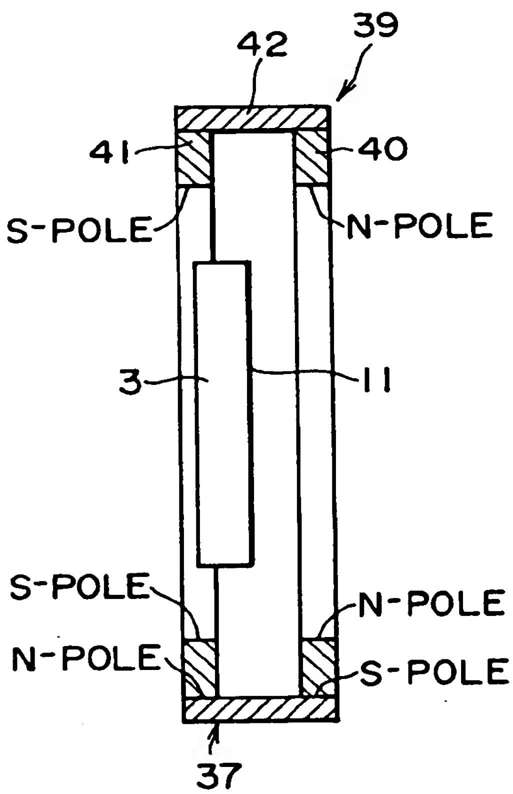
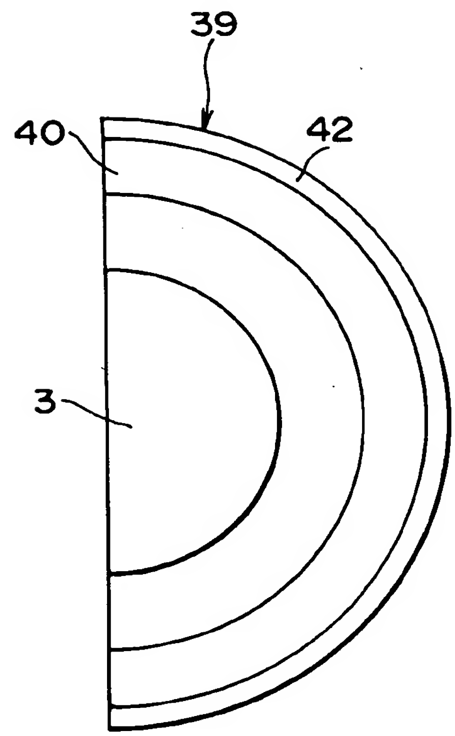


FIG.9A



42
39
41
40
S-POLE
N-POLE
3
11
S-POLE
N-POLE
N-POLE
S-POLE
37

FIG.9B



39
40
42
3

FIG. 11

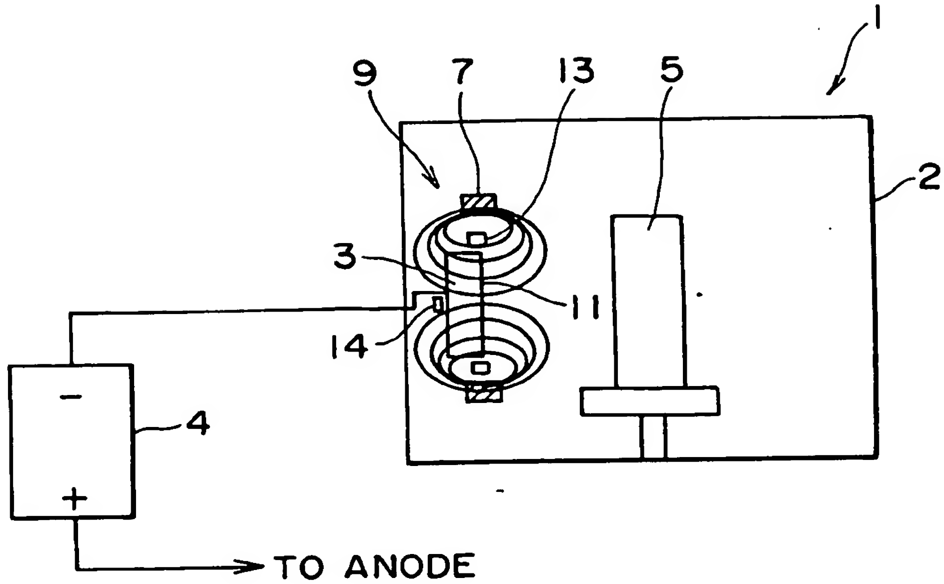


FIG. 12

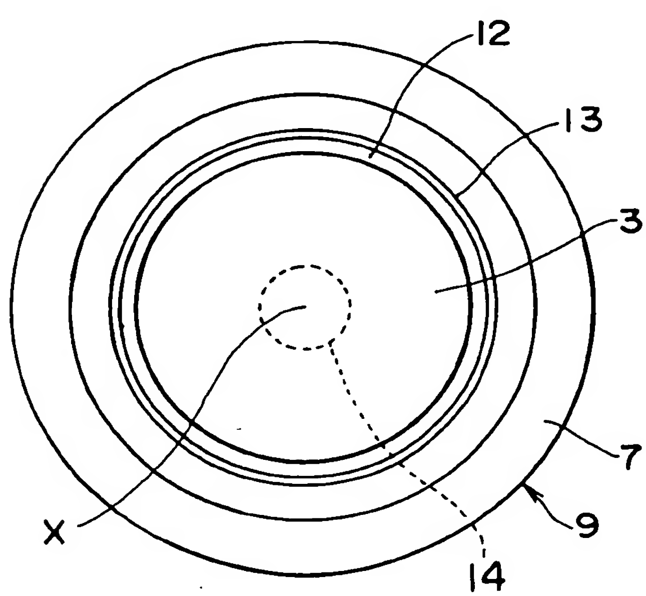


FIG.14A

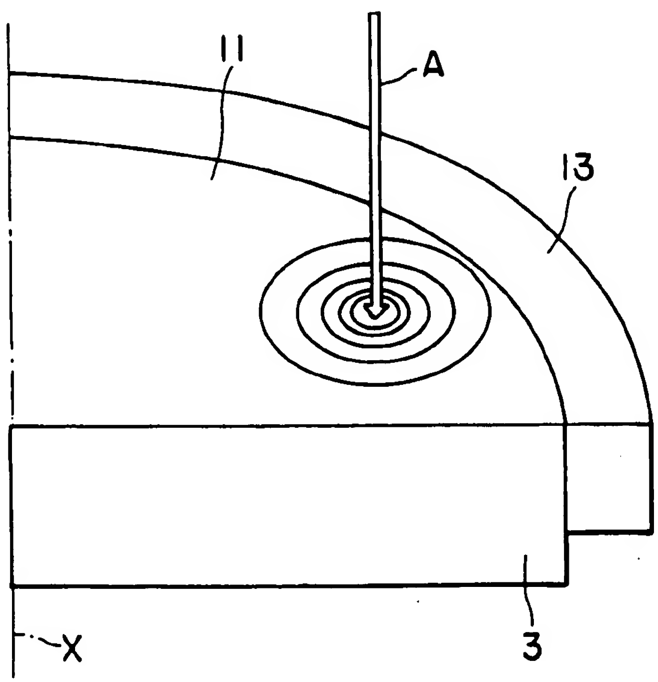


FIG.14B

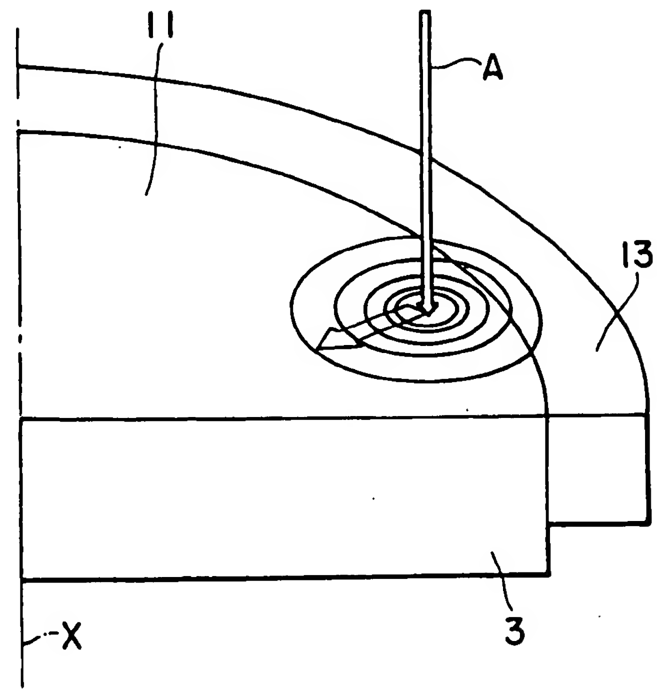


FIG. 16

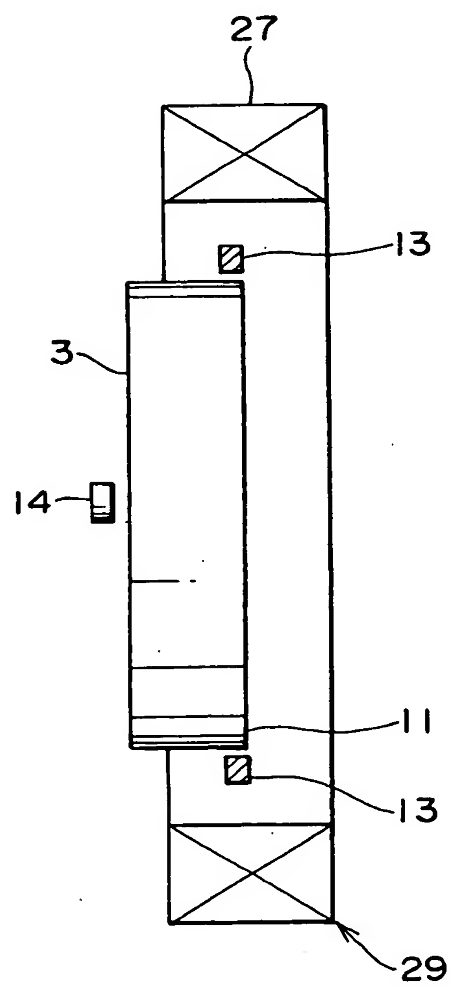


FIG. 18